GEOLOGICAL SURVEY CIRCULAR 359



# URANIUM-BEARING SANDSTONE IN THE WHITE RIVER BADLANDS PENNINGTON COUNTY SOUTH DAKOTA

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## UNITED STATES DEPARTMENT OF THE INTERIOR Douglas McKay, Secretary GEOLOGICAL SURVEY W. E. Wrather, Director

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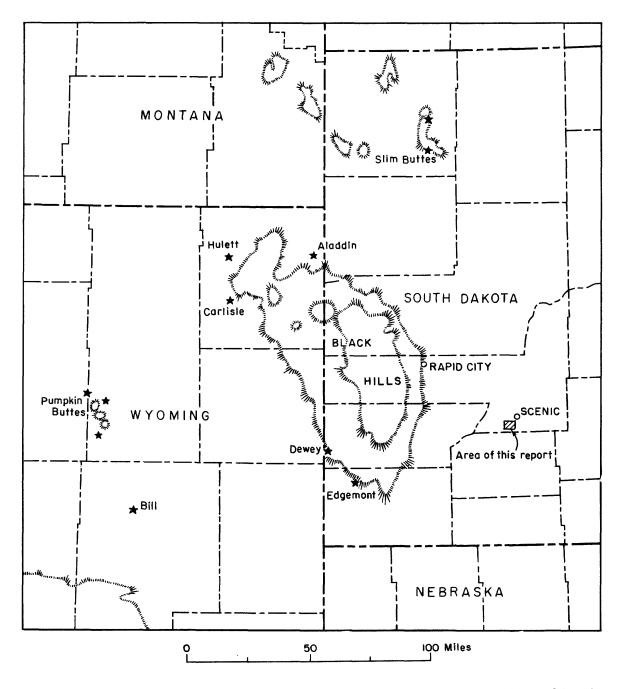


Figure 1. —Index map showing location of area described in this report and its relation to other sandstone-type uranium occurrences (shown by star).

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### ABSTRACT

The uranium mineral uranocircite, a barium uranyl phosphate, occurs in a channel sandstone in the Chadron formation of Oligocene age in the White River badlands, Pennington County, S. Dak. A vertical section of the basal 1-foot of the channel contains 0.25 percent uranium. Small amounts of metatyuyamunite(?) occur in the upper part of a freshwater limestone bed in the Chadron formation, and carnotite occurs in chalcedony veins in the overlying Brule formation, also of Oligocene age. The source of the uranium is thought to have been volcanic ash in the Brule formation and the overlying rocks of Miocene age. Downward moving ground water may have leached this uranium and deposited it in the rocks below.

### INTRODUCTION

Uranium-bearing sandstone was found on the south scarp of Hart Table, near Scenic, Pennington County, S. Dak. (fig. 1), by R. E. Melin,

R. C. Kepferle, and the writers on July 28, 1953. The uranium minerals occur in a channel sandstone in the Chadron formation of the White River group. Reconnaissance was undertaken because rocks of the same formation contain uranium in the Slim Buttes area, <sup>1</sup> in the northwestern part of South Dakota, and overlie uranium deposits in Wyoming (Love, 1952).

An area of 12 square miles was mapped in detail (pl. 1) to provide data that might assist in interpreting the origin of the uranium and guide the search for other occurrences. The area is located about 40 miles southeast of Rapid City and 3 miles southwest of Scenic, a rail shipping point. Access is by a graded road that extends 3 miles west from State Highway 40 at Scenic and 2 miles south across the flat surface of Hart Table to its south tip.

<sup>&</sup>lt;sup>1</sup>Gill, J. R., and Moore, G. W., Carnotite-bearing sandstone in Cedar Canyon, Slim Buttes, Harding County, South Dakota. In preparation as a Geological Survey report.

The White River badlands is the type area for badlands topography. It is characterized by a deeply dissected erosion surface of which Hart Table, Randolph Table, and Sheep Mountain Table are remnants. Between these mesas the tributaries of the Cheyenne River and White River have cut steep-walled valleys. Vegetation is nearly absent except for a few trees along Indian Creek and grass on the mesa tops.

The area was first mapped by the Powell Survey in 1875 (Newton, 1879). It was remapped by Darton (1905) in connection with work on the water resources of the Great Plains. The stratigraphy and paleontology of the rocks of the White River group have been studied in detail by Wanless (1922, 1923), Osborn (1929), and Clark (1937).

N. M. Denson suggested the investigation and gave valuable assistance during all of its phases. W. A. Braddock collected some of the samples used in evaluating the uranium occurrence, and L. R. Page provided valuable suggestions concerning the appraisal of the occurrence. The work was done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

### STRATIGRAPHY

The rocks exposed in the area range in age from Cretaceous to Pleistocene (pl. 1). The Pierre shale of Late Cretaceous age crops out in the valley of Indian Creek in the western part of the area. Unconformably overlying the Pierre shale are conglomerate, sandstone, and bentonitic claystone of the Chadron formation of Oligocene age. The Brule formation, also of Oligocene age, is composed mostly of tuffaceous sandstone and siltstone and conformably overlies the Chadron formation. The Chadron and Brule formations together make up the White River group. In the area studied these formations have a combined thickness of about 600 feet. Lying unconformably on all of these rocks is a thin layer of pediment gravel of Pleistocene age.

### Cretaceous rocks

### Pierre shale

The oldest rocks exposed in the mapped area, an olive-gray to light-olive-gray clay shale, have been assigned to the Pierre shale of Late Cretaceous age.

The Chadron formation unconformably overlies a light brown zone, called the "Interior formation" by Ward (1922), at the top of the Pierre shale. Wanless (1923, p. 197) has suggested that this zone was oxidized and weathered before deposition of the White River group. The zone is about 50 feet thick in most of the area but is absent where the basal rocks of the Chadron formation lie in a great channel cut in the Pierre shale. This channel, called the "Red River Valley" by Clark (1937), is about 70 feet deep and 8 miles wide. The channel trends east and its north wall, not shown on the map (pl. 1), is near the center of the mapped area.

### Tertiary rocks

### Chadron formation

The Chadron formation of Oligocene age is the lowest formation of the White River group and in the area studied rests unconformably on the Pierre shale. It ranges in thickness from 70 to 140 feet and may be divided into two principal lithologic units. The lower unit is present only in the "Red River Valley" channel and consists dominantly of crossbedded sandstone; it also contains some conglomerate and bentonitic claystone (fig. 2). The upper unit is largely yellowish-gray bentonitic claystone, but it also contains channel sandstone and widespread, but thin, discontinuous beds of impure limestone. These limestone beds commonly are partly silicified. Uranium minerals occur locally in the limestone beds and channel sandstone. Four channels have been indicated on the geologic map, plate 1. Other channels are present but were not mapped.

### Brule formation

Overlying the Chadron formation and differentiated from it by a lithologic and color change is the Brule formation of Oligocene age. It is made up of siltstone, silty claystone, and very fine grained sandstone. The light-brown claystone of the Brule formation contrasts in color with the yellowish-gray claystone of the Chadron formation, and the siltstone of the Brule formation is a characteristic grayish orange-pink. The base at most places is marked by a limestone bed at the top of the Chadron formation.

The Brule formation has a maximum thickness of about 500 feet in the area studied and is composed of mixed detrital and volcanic material. The upper 130 feet is almost entirely volcanic ash.

### Quaternary deposits

### Pediment gravel

The accordant upper surfaces of Hart Table, Randolph Table, and Sheep Mountain Table are covered with a veneer of gravel and silt of probable Pleistocene age. These deposits, which are 5 to 15 feet thick, lie on the Missouri Plateau (Fenneman, 1931). In the mapped area the Pleistocene deposits rest on the Brule formation, but the Missouri Plateau surface cuts progressively downward to the northwest and within a few miles the deposits rest on the Chadron formation and Pierre shale.

### Alluvium

Alluvium occurs along Indian Creek and its major tributaries and at a few other places in the area, but the deposits are small and were not mapped.

### STRUCTURE

The rocks of the White River group in the vicinity of the Hart Table uranium occurrence dip about 30 feet per mile to the southeast away from the Black Hills uplift. No faults have been recognized in the area.

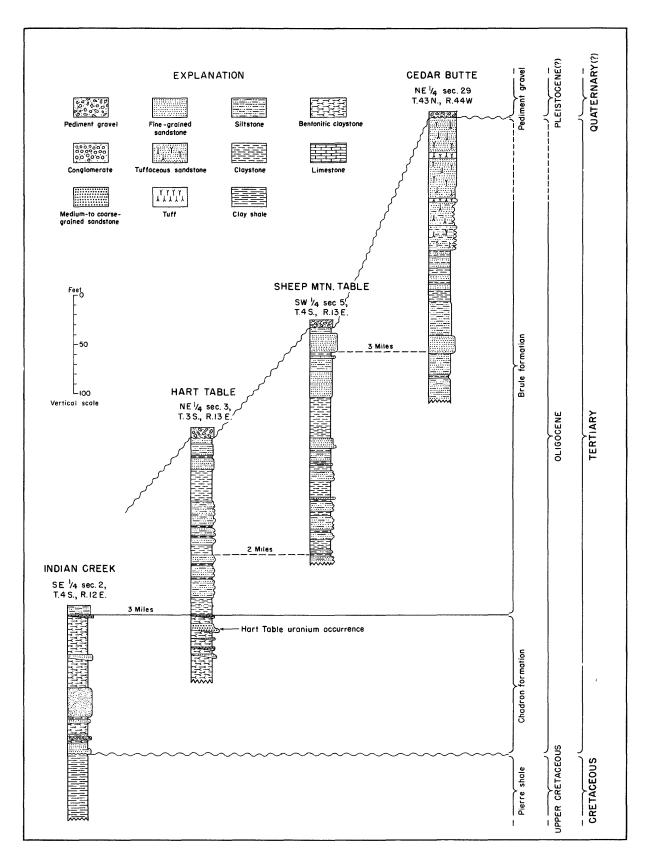


Figure 2. -Stratigraphic sections of rocks in the vicinity of the Hart Table uranium occurrence.

Chalcedony veins as much as 2 inches thick are common in the mapped area. Some sandstone dikes also were found. The chalcedony veins and sandstone dikes fill nearly vertical fractures, some of which are more than 100 feet long. The fractures are present in the Brule formation and rarely extend into the underlying bentonitic claystone of the Chadron formation. Wanless (1923, p. 256) describes dikes of volcanic ash in the Brule formation near Imlay, S. Dak., the filling material of which was clearly derived from a bed of volcanic ash higher in the formation, demonstrating a nearly contemporaneous origin. The chalcedony is generally believed to have been derived by leaching of silica from the volcanic ash in the Brule formation (Lawler, 1923, p. 170; Bump, 1951, p. 45).

Many workers have considered that the fractures have resulted from contraction of the deposits by desiccation (Wanless, 1923, p. 256; Bump, 1951, p. 45), but Smith (1952), noting the vertical extent of the dikes through several beds of differing lithology, the absence of polygonal desiccation pattern, and other evidence, has largely discredited this hypothesis. Lawler (1923, p. 165) plotted the directions of many of the fracture fillings but found no systematic orientation that might suggest a tectonic origin.

In the mapped area it was observed that the fractures are most numerous where the Brule formation overlies the margins of channels in the Chadron formation, particularly along the sides of the "Red River Valley" channel. The origin of the fractures may be due to differential compaction along the sides of underlying channels.

### URANIUM OCCURRENCES

Uranium minerals are most abundant along the axis of a channel sandstone (localities 3-11, pl. 1) on the south flank of Hart Table in the  $NE\frac{1}{4}$  sec. 31, T. 3S., R. 13 E. This channel is near the top of the Chadron formation (fig 3). It is about 500 feet wide, has a maximum thickness of 7 feet, and is at least 1 mile long. The uranium minerals, however, are exposed through only a short part of its total length. The channel filling is composed of yellowish-gray coarse-grained sandstone which is moderately well sorted. The basal 2 feet are very well indurated and form a prominent ledge (fig. 4). The channel is directly underlain by an impermeable bed of bentonitic claystone.

The uranium mineral has been identified by X-ray diffraction methods as uranocircite by W. F. Outerbridge.

This yellow-green nonfluorescent barium uranyl phosphate is associated in the rock with barite and apatite. It is disseminated through the lower 2 feet of the channel sandstone, and the most intense mineralization has been in the basal few inches of the channel. Some uranocircite is present in fractures in the top inch of the underlying bentonite. Analyses of these rocks are given in the table below.

Metatyuyamunite(?), a calcium uranyl vanadate, occurs at one place in a bed of freshwater limestone in the Chadron formation in the  $NE_{\frac{1}{4}}$  sec. 36, T. 3S., R. 12 E. This limestone bed marks the top of the Chadron formation and is about 2 feet thick. The bed is partly replaced by chalcedony. The metatyuyamunite(?) is in the top inch of the bed.

In addition to uranium minerals in sandstone and limestone in the Chadron formation, efflorescent coatings of carnotite, a potassium uranyl vanadate, occur on chalcedony veins in the Brule formation at several localities (fig. 5). These coatings are very thin and are only found on the outer surfaces of the vertical or near-vertical veins.

### Origin

Uranium occurrences in the White River badlands probably originated in one of the following ways: By deposition of uranium minerals with the original sediments in the channel and possible later redistribution by groundwater; by deposition from hydrothermal solutions; and by deposition from groundwater solutions that have leached the uranium from overlying volcanic ash.

The uranium deposits of the Colorado Plateau probably originated at about the same time, possibly by the concentration of uranium shortly after deposition of the enclosing rocks (Fischer, 1942).

Sediments in the channel sandstone in the White River badlands probably were partly derived from the Black Hills, 50 miles to the west, where important uranium deposits occur in the Inyan Kara group of Early Cretaceous age (Page and Redden, 1952). Uranium derived from the erosion of these deposits, or from deposits in the pre-Cambrian rocks of the Black Hills, could have been localized at the time the sandstone in the channel was laid down. However, it would be difficult to explain the concentration of uranium in the chalcedony veins in the overlying Brule formation by the same process.

Analyses of samples collected in the White River badlands [Analyses by: E. J. Fennelly, S. P. Furman, Wayne Mountjoy, and J. E. Wilson]

Map locality	Lab. number	Material	Type of sample	Equivalent uranium (percent)	Uranium (percent)
1 2 3 4 5 6 7 8 9 10 11 12	D-98835 D-96198 D-98836 D-98839 D-96199	Limestone	Grab	0.017 .007 .12 .006 .008 .13 .014 .20 .020 .013	0.023 .008 .22 .005 .007 .24 .013 .25 .022 .012

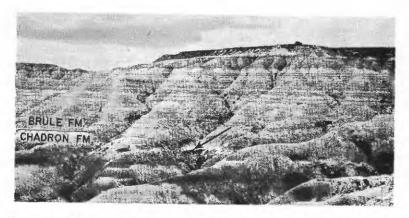


Figure 3.—The Chadron and Brule formations in the White River badlands. Arrow indicates exposure of uranium-bearing channel sandstone.

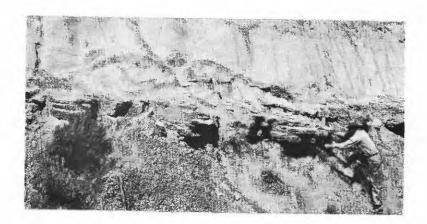


Figure 4. - Mineralized channel sandstone in the Chadron formation.

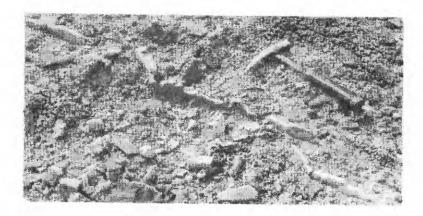


Figure 5.—A carnotite-bearing chalcedony vein in the Brule formation.

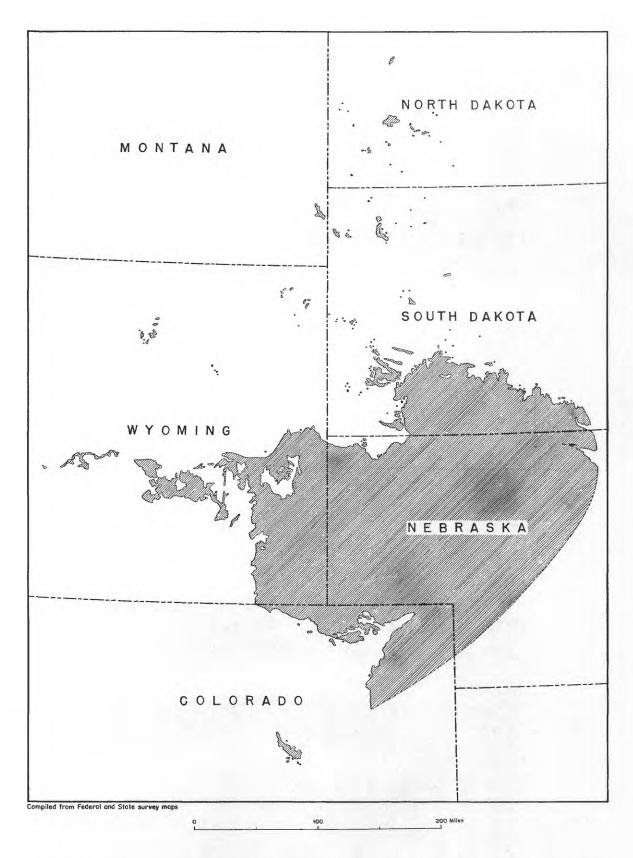


Figure 6. -Map showing areal distribution of rocks of the White River group in the Rocky Mountain region.

The chalcedony veins fill fractures that are thought to have been caused by differential compaction of the rocks before lithification. They might be considered to be hydrothermal deposits; however, when traced downward, they are not found to pass through the bentonitic claystone of the Chadron formation. No evidence of hydrothermal activity has been reported in the entire region of the White River badlands.

Many writers believe that the chalcedony was derived from silica leached by ground water from volcanic ashin the enclosing rocks (Lawler, 1923, p. 170; Bump, 1951, p. 45). The source that seems to most satisfactorily explain the geologic relations is the overlying tuffaceous rocks of the Brule formation, and rocks of Miocene age that were removed by erosion after the fractures were filled but which are still present southeast of the mapped area.

N. M. Denson, G. O. Bachman, and H. D. Zeller (written communication, 1950) first suggested that some uranium deposits may have had their source from pyroclastic debris containing small amounts of uranium in Tertiary rocks. Others have considered this type of origin for uranium-bearing sandstone deposits of Wyoming (Love, 1952), Utah (Proctor, 1953), the Colorado Plateau (Gruner, 1954), and other areas.

The rocks of the Brule formation contain on the average about 0.001 percent uranium. Gill and Moore 2 have shown that spring water issuing from the White River group and the Arikaree formation in the Slim Buttes area, Harding County, S. Dak., contains about 10 to 30 times as muchuranium as water from the nontuffaceous Ludlow and Hell Creek formations. The spring water also contains significant concentrations of vanadium. The average uranium content of water from 26 springs in the White River group and Arikaree formation is 41 parts per billion, whereas water from 8 springs in the Ludlow and Hell Creek formations averages 4 parts per billion uranium. Even the waters from these nontuffaceous formations may have been enriched by the nearby tuffaceous rocks, as the uranium content of water long distances from known sources of uranium is even lower. Sheldon Judson and Kenneth Osmond (written communication, 1953) obtained an average uranium content of only 0. 4 parts per billion uranium from 42 well samples in Wisconsin, and the uranium content of the ocean is only about 1 part per billion (Koczy, 1950).

It is suggested that the uranium occurrences in the White River badlands were formed over a long period of time by the precipitation of uranium from groundwater solutions. The source of the uranium is believed to have been from volcanic ash in the rocks of upper Oligocene and Miocene age. Meteoric water moving downward and laterally may have leached uranium and carried it until a favorable physical and chemical environment for deposition was reached in fractures in the Brule formation and channel sandstone and limestone beds in the Chadron formation. The volcanic ash may also have been the source of the silica in the chalcedony veins and silicified limestone.

### SUGGESTIONS FOR PROSPECTING

An airborne radioactivity survey of part of the White River badlands was conducted by the U.S. Geological Survey. This survey showed that the rocks of the White River group have a much higher radioactivity than the

underlying rocks. In addition, spring-water samples from widespread areas in these rocks contain high concentrations of uranium. A sample from sec. 13, T. 31 N., R. 70 W., Converse County, Wyo., contains 150 parts per billion uranium (M. L. Troyer, personal communication), and a sample from sec. 21, T. 10 N., R. 60 W., Weld County, Colo., contains 12 parts per billion (H. A. Tourtelot, personal communication).

The White River group is exposed chiefly in North and South Dakota, Wyoming, Colorado, Nebraska, and Montana (fig. 6). Prospecting might be rewarding in these States both in the White River group and in underlying rocks, which may have derived uranium from the White River group. Tuffaceous rocks principally of Miocene age may also be important sources of uranium. These rocks mantle parts of the Great Plains from North Dakota to Texas.

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<sup>&</sup>lt;sup>2</sup>Gill, J. R., and Moore, G. V., op. cit.

GEOLOGY OF PART OF THE WHITE RIVER BADLANDS, PENNINGTON COUNTY, SOUTH DAKOTA